

Effect of Σ -beam Asymmetry Data on Fits to Single Pion Photoproduction off Neutron

I.I. Strakovsky*, R.A. Arndt†, W.J. Briscoe, M.W. Paris, R.L. Workman
The George Washington University, Washington, DC 20052, USA

We investigate the influence of new GRAAL Σ -beam asymmetry measurements on the neutron in multipole fits to the single-pion photoproduction database. Results are compared to those found with the addition of a double-polarization quantity associated with the sum rule.

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I. INTRODUCTION

Only with good data on both proton and neutron targets one can hope to disentangle the isoscalar and isovector EM couplings of the various baryon resonances, as well as the isospin properties of the non-resonant background amplitudes. In particular, the simple quark model predicts several resonances that couple much stronger to the neutron than to the proton. The lack of $\gamma n \rightarrow \pi^- p$ and $\gamma n \rightarrow \pi^0 n$ data does not allow us to be as confident about the determination of neutron couplings relative to those of the proton.

Some of the N^* baryons, $N(1675)5/2^-$, for instance, have stronger electromagnetic couplings to the neutron than to the proton but parameters are very uncertain. PDG [1] estimate for the $A_{1/2}$ and $A_{3/2}$ decay amplitudes of the $N(1720)3/2^+$ state are consistent with zero, while the recent SAID determination [2] gives small but non-vanishing values. The reason for the disagreement between the PDG estimate for the $A_{1/2}$ decay amplitude and the recent SAID determination [2] is also unclear. Other unresolved issues relate to the $N(1700)3/2^-$ and second P_{11} , $N(1710)1/2^+$, that are not seen in the recent GW πN partial-wave analysis (PWA) [3], contrary to other PWAs used by the Particle Data Group [1].

New, high quality data on $\gamma n \rightarrow \pi^- p$ and $\gamma n \rightarrow \pi^0 n$ are needed to shed light on these issues, and the tagged-photon hall at GRAAL offered a state-of-the-art facility to obtain such data. Here we report on an analysis included novel Σ -measurements, covering incident photon energies from threshold ($E_\gamma = 707$ MeV) up to $E_\gamma = 1500$ MeV. The present measurement of Σ s for $\vec{\gamma} n \rightarrow \pi^- p$ [4] and for $\vec{\gamma} n \rightarrow \pi^0 n$ [5] is part of an extensive program at the GRAAL to provide data of unrivaled quality on charged and neutral meson photoproduction on the neutron, which includes polarized beam observable in addition to the cross sections.

II. NEW GRAAL MEASUREMENTS FOR Σ ON THE NEUTRON

To gauge the influence of new GRAAL data and their compatibility with previous measurements, the GRAAL Σ s have been included in a number of fits using the full SAID database for $\gamma N \rightarrow \pi N$ up to $E_\gamma = 2.7$ GeV [7]. The impact of new data on the SAID PWA can be understood from the comparison of the new SAID fit MA09 [4], which involves new GRAAL data, with the previous SAID fit SP09 [2] and MAID2007 results [6].

216 Σ s for $\pi^0 n$ final state at $E_\gamma=703-1475$ MeV and $\theta=53-164^\circ$ with 99 Σ s for $\pi^- p$ final state at $E_\gamma=753-1439$ MeV and $\theta=33-163^\circ$ GRAAL data have been added to the GW SAID database [7]. We have to notice that this GRAAL $\pi^0 n$ contribution doubled the World database for this reaction. Our best fit MA09 [4] for $\pi^0 n$ and $\pi^- p$, reduced initial $\chi^2/\text{dp}=223$ and 89 (SP09 [2]) to 3.1 and 4.9, respectively. It shows, in particular, that previous $\pi^- p$ measurements provided a better constraint vs. $\pi^0 n$ case.

In Figs. 1 and 2, we show the excitation functions for several production angles. The number of the distributions shown is enough to illustrate the quality of new GRAAL data, the main features of the $\gamma n \rightarrow \pi N$ dynamics at the measured energy range, and the impact of the present data on PWAs. The most noticeable effect of the present data

* Electronic address: igor@gwu.edu

† Deceased

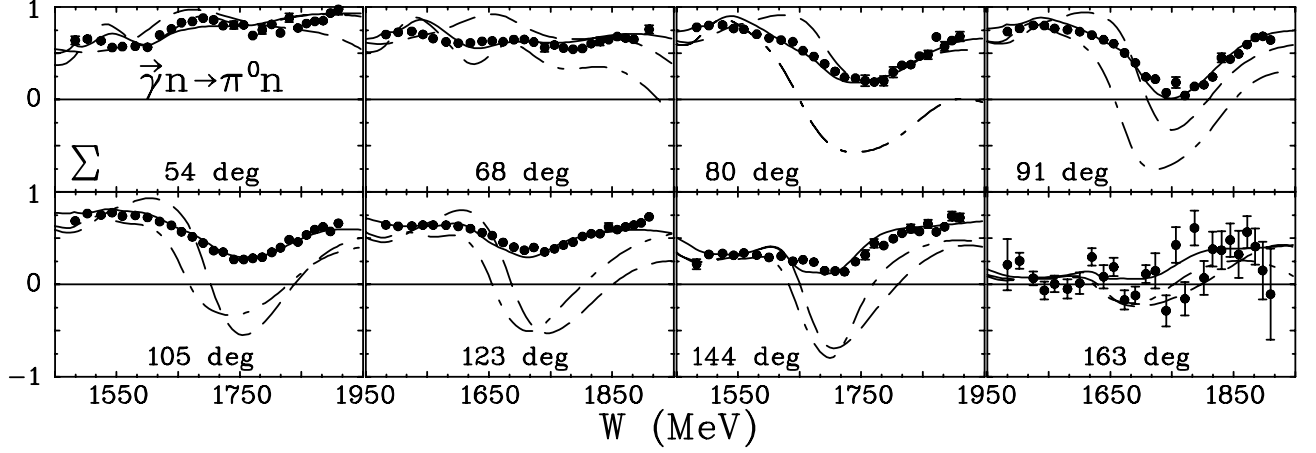


FIG. 1: Σ -beam asymmetry for $\bar{\gamma}n \rightarrow \pi^0 n$. Data from GRAAL Collaboration [5]. Solid lines correspond to the SAID-MA09 solution (GRAAL data included in the database) [4]. Dash-dotted (dashed) lines show the SAID-SP09 [2] (MAID2007 [6]) (GRAAL data excluded in the database).

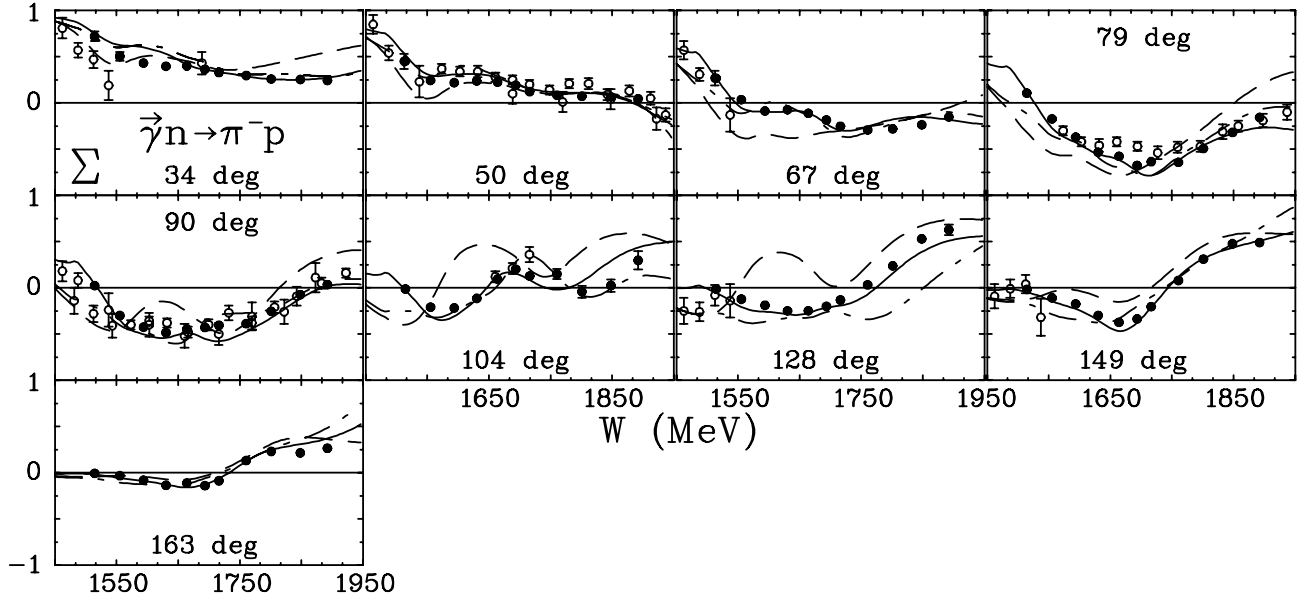


FIG. 2: Σ -beam asymmetry for $\bar{\gamma}n \rightarrow \pi^- p$. Data from GRAAL Collaboration [4]. The notation of the PWA solutions is the same as in Fig. 1

on the new MA09 is due to very good measurements of the medium-angle (65° – 140°) Σ s for W in the range above 1650 MeV. Earlier, this angular region either had been measured with worse accuracy or could only be reached by extrapolation.

The difference between our MA09 and SP09 results for the neutron target is visible specifically for S_{11nE} (Fig. 3). It is observed above $E_\gamma \sim 400$ MeV while modified MAID2007 shown a significant changes vs. MAID2007 [5] above 1 GeV (see Fig. 7 at Ref. [5]).

The difference between previous pion photoproduction and new GRAAL measurements may result in significant changes in the neutron couplings.

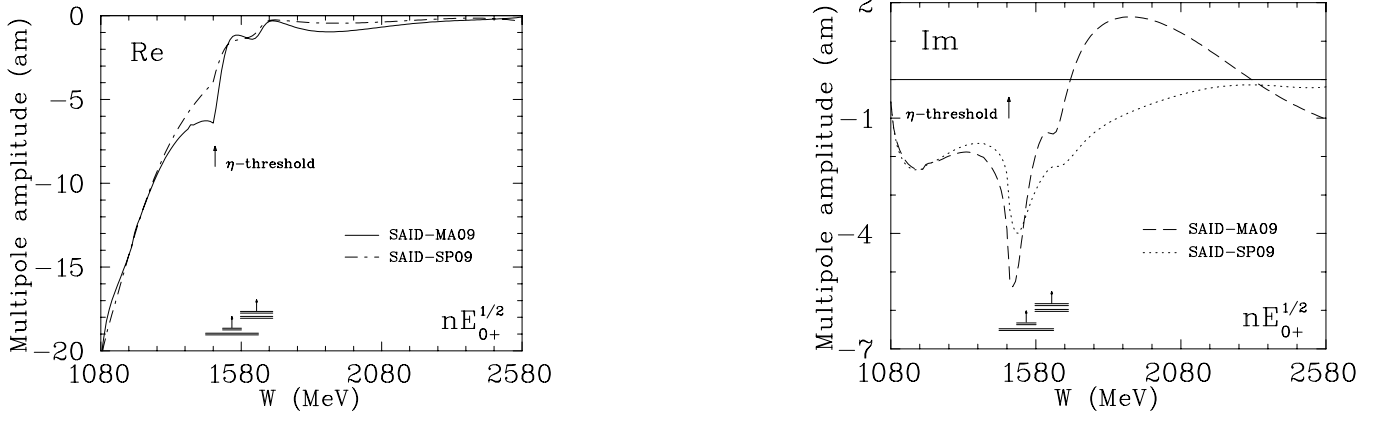


FIG. 3: The multipole amplitude $S_{11nE} ({}_nE_{0+}^{1/2})$. (a) Re and (b) Im parts show. The vertical arrows indicate W_R (Breit-Wigner mass) and the horizontal bars show the full and partial width Γ and $\Gamma_{\pi N}$ associated with the SAID solution SP06 for πN [3].

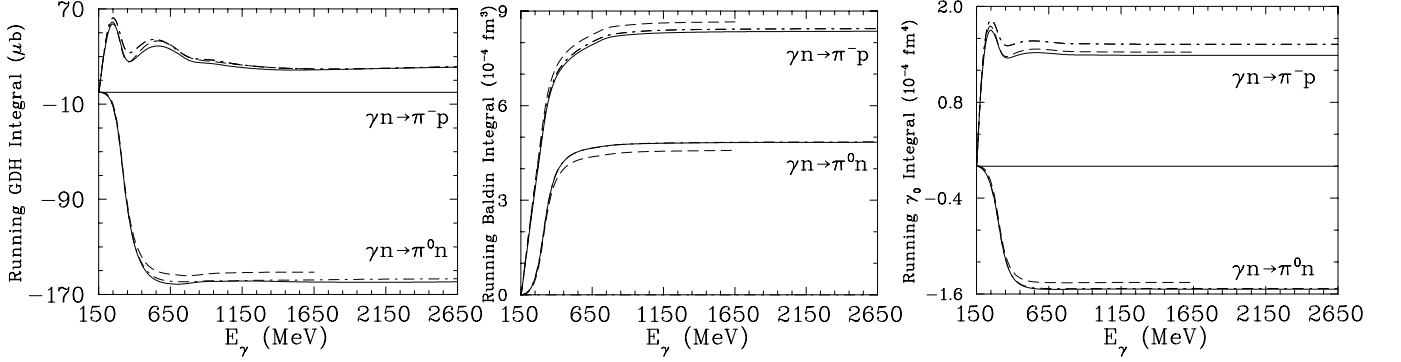


FIG. 4: Running (a) GDH, (b) Baldin, and (c) forward spin polarizability γ_0 integrals for the neutron target. The solid (dash-dotted) lines represent the SAID-MA09 (SAID-SP09) solution. Dashed lines show the MAID2007 predictions.

III. HELICITY-DEPENDENT PHOTOABSORPTION CROSS SECTIONS ON THE NEUTRON

The amplitudes obtained in our analyses can be used to evaluate the single-pion production component of several sum rules, in particular GDH, Baldin, and forward spin polarizability [8]. In Table I, we summarized our results for the neutron target.

The running integrals are shown in Fig. 4. The evaluation of sum rules (GDH, Baldin, and forward spin polarizability) for the neutron target and for a single pion contribution exhibits convergence by 1 GeV. Agreement with Mainz is good. Clearly, calculations above 450 MeV have to take into account contributions beyond single-pion photoproduction.

TABLE I: Comparison of the recent SAID-MA09, SAID-SP09, and MAID2007 calculations for the GDH, Baldin and the forward spin polarizability from threshold up to 2.5 GeV in W (for MAID up to 2 GeV) and displayed as MA09/SP09/MAID2007.

Reaction	GDH (μb)	Baldin ($10^{-4} fm^3$)	γ_0 ($10^{-4} fm^4$)
$\gamma n \rightarrow \pi^- p$	21/ 21/ 20	8.4/8.4/8.7	1.4/ 1.5/ 1.4
$\gamma n \rightarrow \pi^0 n$	-159/-157/-151	4.8/4.8/4.6	-1.5/-1.5/-1.5

Acknowledgments

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- [1] K. Nakamura, et al. (Particle Data Group), *J. Phys. G* **37**, 075021 (2010).
 - [2] M. Dugger, et al. (CLAS Collaboration), *Phys. Rev. C* **79**, 065206 (2009).
 - [3] R.A. Arndt, W.J. Briscoe, I.I. Strakovsky, and R.L. Workman, *Phys. Rev. C* **74**, 0605082 (2006).
 - [4] G. Mandaglio, et al. (GRAAL Collaboration), *Phys. Rev. C* **82**, 045209 (2010).
 - [5] R. Di Salvo, et al. (GRAAL Collaboration), *Eur. Phys. J. A* **42**, 151 (2009).
 - [6] D. Drechsel, S.S. Kamalov, and L. Tiator, *Eur. Phys. J. A* **34**, 69 (2007).
 - [7] The SAID website contains data and fits for this and a number of other medium-energy reactions:
<http://gwdac.phys.gwu.edu>.
 - [8] R.A. Arndt, W.J. Briscoe, I.I. Strakovsky, and R.L. Workman, *Phys. Rev. C* **66**, 055213 (2002).